Space Weather Technical Forecast

Issued on Friday, 24 December 2021 at 13:03 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Reducing risk of G1/Minor storms day 1 (24th). Chance of M-class flares (R1/R2 Radio Blackout), with slight chance of X-class (R3 Radio Blackout). Active fluence easing day 1 or 2 (24th or 26th)

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours, with numerous C-class flares observed. There are eight sunspot regions, however flaring has primarily been from AR2907 Ehc/beta and AR2908 Bxi/Beta in the southwest. AR2907 remains the most complex region, and has been developing further as it approaches the southwest limb, whilst AR2908 shows signs of decay despite recent flaring. A C-flare was also observed from AR2917 Dao/Beta in the southeast whilst AR2916 Eho/beta and AR2918 Dsi/Beta in the eastern hemisphere have the potential for notable flares. All other regions are small and magnetically simple, with some decay occurring.

No Earth-directed CMEs were observed in available imagery in the last 24 hours.

Solar Wind / Geomagnetic Activity: An anticipated CME from the 20th has yet to arrive. Solar winds speeds as measured by DSCOVR at L1 have been gradually declining, from 510 km/s to be slightly elevated at 430 km/s, as Earth continues exiting the recent fast wind enhancement from CH35. The density fallen from just above average near average levels. Interplanetary magnetic field strength (IMF), Bt has been weak throughout, below 5 nT, with the north-south component, Bz varying from -4nT to +4nT. Phi angle has been predominantly negative (towards the Sun). Geomagnetic activity was Quiet (Kp 0-2).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at background levels. The high energy electron flux (greater than 2 MeV) was High until 23/2310 UTC, peaking at 2410 pfu at 23/1605 UTC, then again from 24/0910 UTC. The associated 24-hour integrated fluence rose above the Active threshold by 23/2100 UTC, and peaked just above this levels. A fluence of 1.09e8 integrated pfu was recorded at 24/0000UTC

Four-Day Space Weather Forecast Summary

Solar Activity: Low solar activity is expected to continue through the forecast period, with further C-class flares expected, a chance (40%) of further M-class flares and a slight chance (15%) of an X-class. This risk reducing day 4 (27th) with AR2907 rotating off the Earth-facing disc day 3 (26th).

Solar Wind / Geomagnetic Activity: There are three potentially Earth-directed CMEs. The first from an M-class flare from AR2908 on the 20th, was expected late 23rd or early 24th, but has yet to arrive. This could still arrive later on day 1 (24th) but with a decreasing chance of notable impacts and low confidence The other two CME's are from the 21st (likely from the C4-flare of AR2809) and 22nd (from a further M-flare of 2808). These are both very weak, probably missing just ahead, but could glance Earth on the 26th or 27th. Outside of potential CME influence the currently elevated solar winds are likely to continue to gradually ease, as the effects of CH35 wane, until day 4 (27th) when the fast wind of CH37 is expected to arrive. Quiet geomagnetic conditions, could become Unsettled to Active for a period with any CME arrival, most likely day 1

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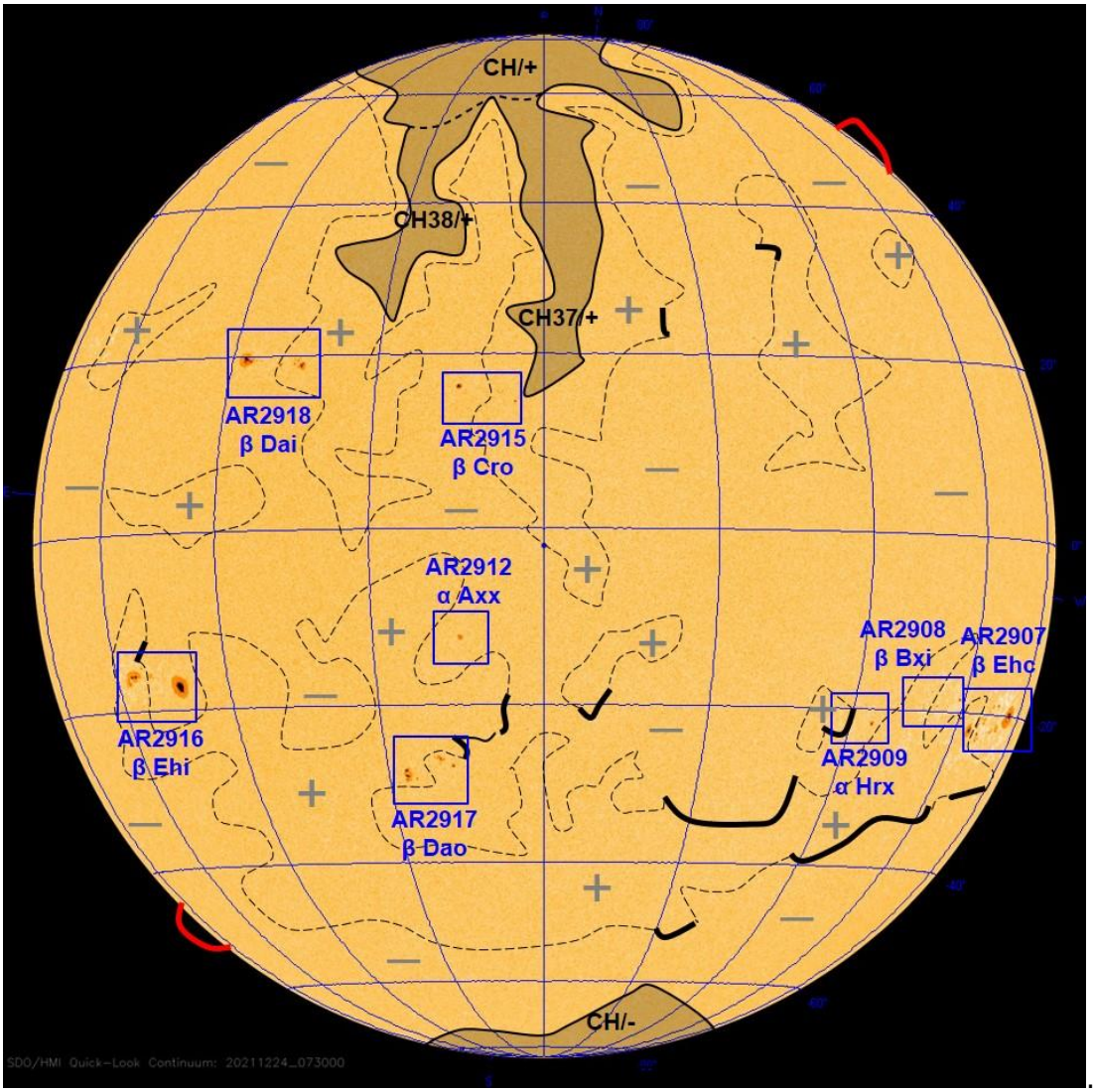
(24th) with a slight chance day 3 or 4 (26th or 27th). There is a slight chance of G1/Minor Storm intervals. The arrival of the fast wind of CH37 later day 4 (27th) is expected to increase activity to Active with a slight chance of G1/Minor Storms.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at background levels and below the S1 level, although there is a slight chance for some increased flux from any significant flare activity. Currently Moderate to High high energy (greater than 2 MeV) electron flux at GEO is expected to drop out with any CME arrival Otherwise, a gradual reduction in peak values is anticipated, with the associated 24 hour fluence falling below the Active level either late day 1 (24th) or day 2 (25th).

Figure 1. Solar Analysis Valid 24/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

An Earth-directed CME which left the Sun on the 20th is anticipated to glance Earth early today (24th). There are two further CMEs of interest for the forecast, although both are weak and likely missing, passing just ahead of Earth. The first is a CME which is visible on STEREO A, likely originating from either a filament eruption at around 21/1730 UTC in the southeast disc, or a C4 flare from AR2909 at 21/1914 UTC, or a combination of the two. A further very narrow CME occurred on the morning of the 22nd, perhaps associated with the M-flare of AR2908. These CMEs are expected to pass on the 26th or 27th, with glancing influence possible on either day.

Otherwise solar winds are currently easing after recent prolonged enhancement due to the fast wind of CH35, and in the absence of any CME enhancement would be expected to decline towards background through the period. The next coronal hole fast wind enhancement is likely to be from CH37, a southern extension of the northern crown, most likely arriving later on day 4 (27th), though an earlier arrival cannot be ruled out.

Quiet conditions, could become Unsettled to Active for a period with any CME arrival, most likely day 1 (24th) with a slight chance day 3 or 4 (26th or 27th). There is a slight chance of G1/Minor Storm intervals. The arrival of the fast wind of CH37 later day 4 (27th) is expected to increase activity to Active with a slight chance of G1/Minor Storms.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	5	5	20
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Name	Liftoff Time	Long	Lat	Radial Speed (km/s)	Half Angle
CME-202112-016	22/12/2021 07:20	28W	22S	475	10
CME-202112-015	21/12/2021 19:15	30W	20S	319	22
CME-202112-012	20/12/2021 12:36	11E	14S	625	34

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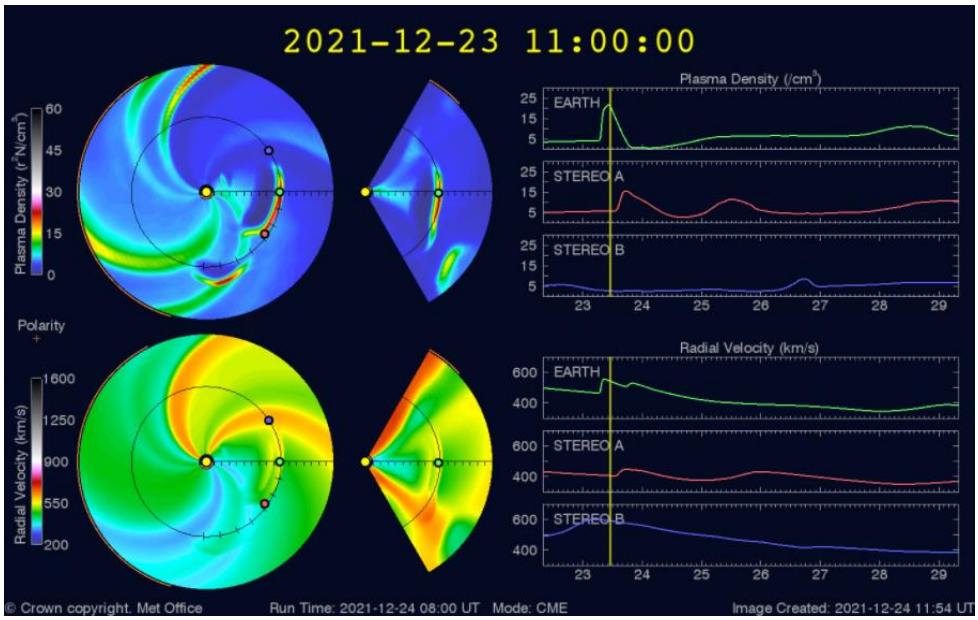
Figure 2: Enlil and ensemble showing expected CME arrival on the 23rd. currently not observed, but low confidence in analysis, so could yet arrive day 1 (24th). Slight ensemble signal for potential arrivals of further weak CMEs from 21st and 22nd.



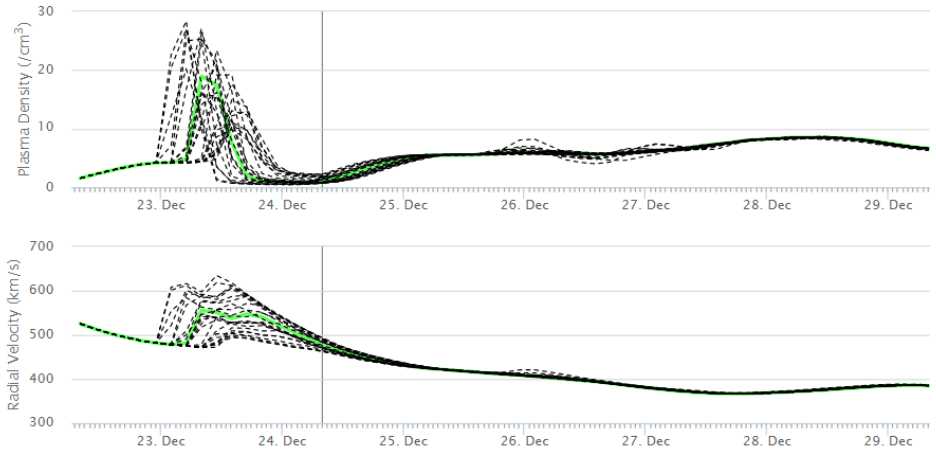
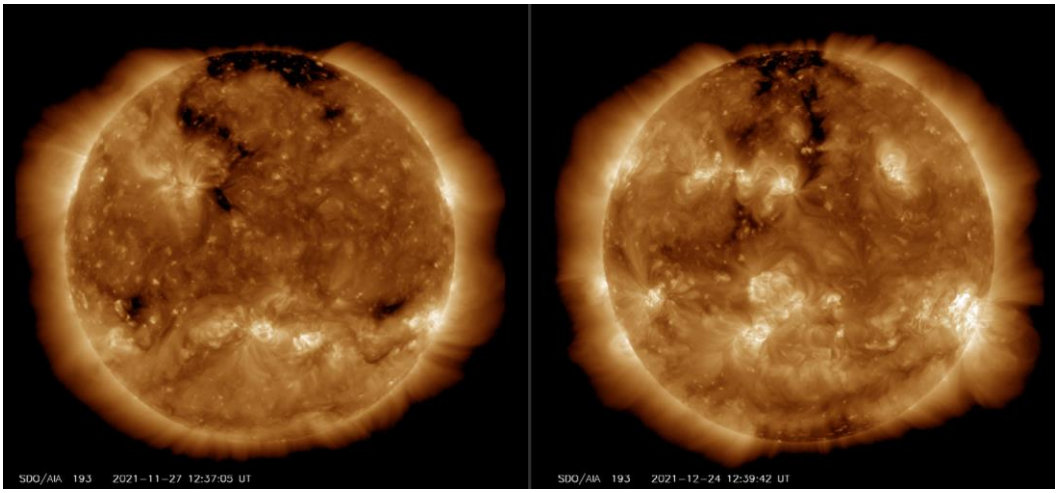


Figure 3: SDO aia 193 of previous rotation (left) and current (right). Different structure of northern crown CH, limiting the guidance of persistence forecasting



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Radio Blackouts - X-Ray Flares:

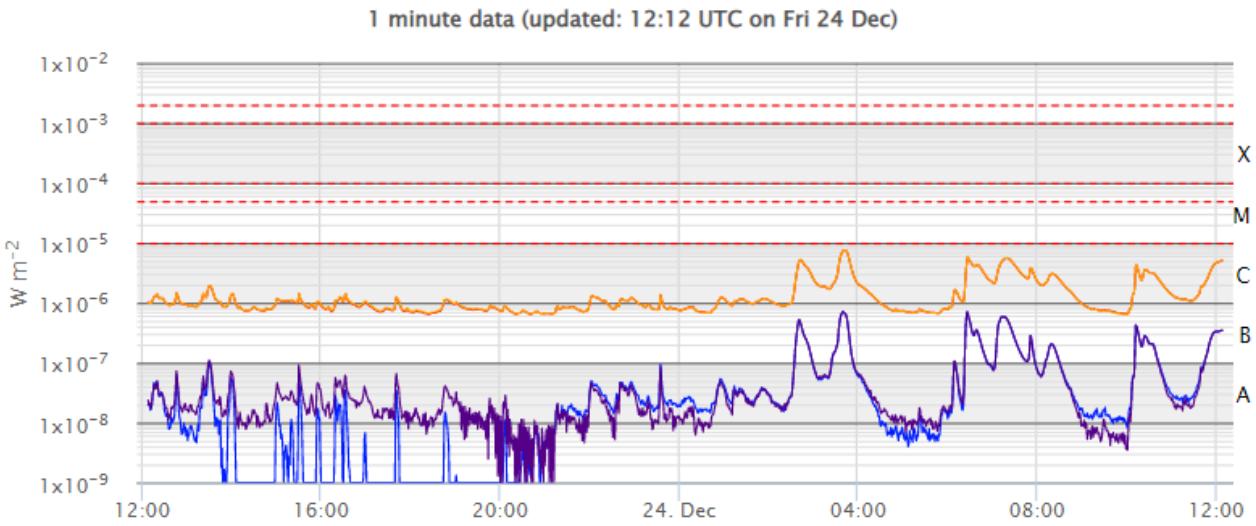
There are currently 8 sunspot regions on the disc. Whilst activity is currently Low, there have been frequent C-flares during the last 12 hours from AR2907 Ehc/Beta and AR2908 Bxi/Beta. The former is the most complex spot on the disc, but now approaching the southwest limb and becoming harder to accurately analyse. Despite this, a large symmetric leader coupled with penumbra laden intermediaries makes this a statistically rare and fairly complex classification. This has class has historically not produced X-class flaring, but is considered to still have a slight chance of X-ray flaring due to the small sample size. The latter, whilst gradually decaying to a simple classification continues to show some low level flaring.

There are three other spots of notable interest. AR2916 Ehi/beta is the largest, but magnetically simpler group, in the southeast quadrant, with current changes evident around its smaller trailer spot. AR2917 Dao/beta is also in the southeast, and whilst much smaller has some magnetic complexity, with a C-class flare observed overnight. AR2918 Dai/Beta in the northeast has been largely stable and magnetically simple but moderately sized. All these spots have a low risk of M-flares. The other sunspot containing Active regions, AR2909 Hrx/alpha, AR2912 Axx/Alpha, AR2915 Cro/Beta are all currently stable with flaring unlikely.

Overall, activity is expected to remain Low, with a chance of M-flares (R1/R2 Radio Blackouts) and a slight chance of low X-class fares (R3 Radio Blackouts). This risk receding later in the period as AR2907 rotates off the disc during day 3.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	40	40	40	20
Very Active	R3 to R5 X Class	No	15	15	15	5

Figure 4: GOES-16/17 X-ray flux, showing recent flaring of AR2908 and AR2907



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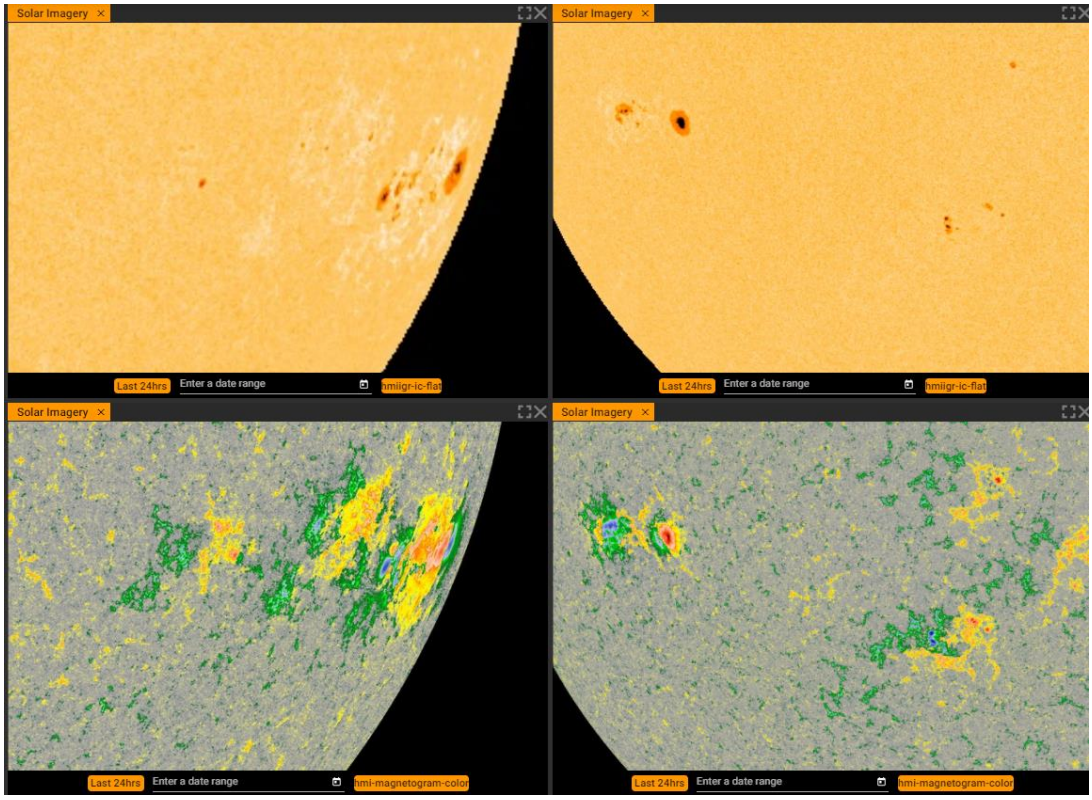
Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at background levels and expected to persist at these levels. AR2907 is in a geoeffective location for proton storming, with this region having the greatest potential for generating a significant flare and a proton rich eruption. This risk is maintained as AR2907 rotates off the disc day 3 and into day 4 (26th into 27th), due to the potential for flaring from around the limb, from which Earth-directed protons are still possible due to the Parker Spiral.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: SDO hmi-intensitygram and magnetogram, showing AR2809, AR2808 and AR2807 in the first column, and AR2816, AR2818 and AR2815 in the second column (all from left to right).



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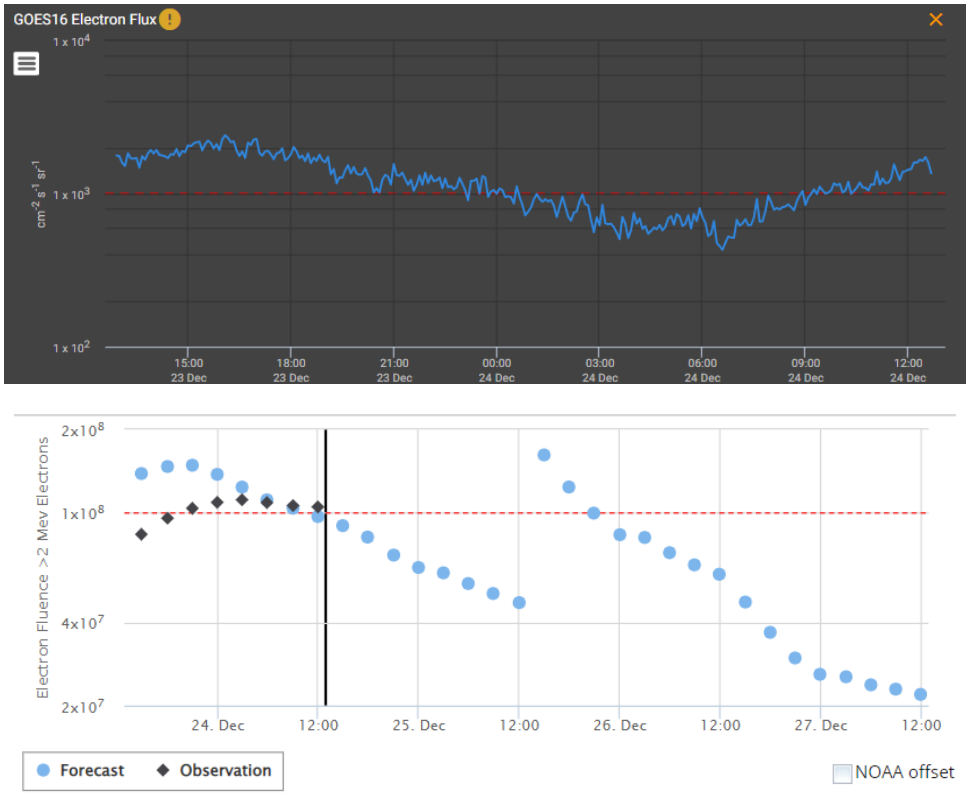
High Energy Electrons Event (≥ 2MeV):

The high energy electron Flux as observed by GOES-16 is varying diurnally from moderate to high levels, although peak values appear likely to be lower or similar on the 24th than on the 23rd. With no CME yet observed, these levels have persisted, and are likely to be maintained until any arrival occurs. Confidence is now low with this arrival, and there is the potential for these levels to be maintained until the onset for the fast winds of coronal hole 37 on day 4 (27th). Any CME arrival is likely to cause a dropout in values, before an uncertain recovery day 2 and day 3 (25th and 26th), but likely moderate with a chance of reaching high at peak of the diurnal cycle

The associated fluence is currently Active (above 1e8 integrated pfu), however with flux levels currently running below those on the 23rd, a declining trend is expected, likely falling below the Active threshold buy the end of day 1 or early day 2 (24th or 25th). Any CME arrival is likely to causes these values to fall further and faster, but otherwise a gradual decay in values is anticipated, with REFM giving a good indication of the trend.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	Yes	100	40	20	10
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 6: GOES-16 >2MeV Electron flux with associated fluence and REFM



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